

RAIN ATTENUATION COMPENSATION METHOD USING ADAPTIVE TRANSMISSION TECHNIQUE AND SYSTEM USING THE SAME

TECHNICAL FIELD

The present invention relates to a rain attenuation compensation method in a
5 satellite communication system and an apparatus using the same. More particularly, it
relates to a rain attenuation compensation method in a satellite communication system
using a high frequency band over Ku-band, which uses an adaptive transmission technique,
measures/predicts the quality of a received signal, and allocates a transmission technique
proper to a present rain attenuation value. The invention also relates to a satellite
10 communication system employing a rain attenuation compensation method using the
adaptive transmission technique.

BACKGROUND OF THE INVENTION

In general, conventional rain attenuation compensation methods mainly uses
either power control techniques or diversity techniques. In recent times, new techniques
15 have been developed to compensate rain attenuation by using an adaptive transmission
technique.

The rain attenuation compensation methods using the power control
techniques are disclosed in U.S. Pat. Nos. 4261054 and 4731866, which amplify signal
powers by a degree of signal attenuation if signal attenuation occurs due to rain. But, the
20 prior arts should include a high power amplifier for supplementing the power margin at the
time when the system is designed, and thus causes economical inefficiency.

Another rain attenuation compensation method using the diversity
techniques requires to install additional earth station, additional frequency band or satellite
according to the kinds of diversity, and therefore causes even serious economical problem.

25 Rain attenuation compensation methods using adaptive transmission
techniques are disclosed in U.S. Pat. Nos. 4309764, 4301533, 4837786, and 4047151, that
describe a method for allocating a spare time slot to either a user or earth station

experiencing excessive attenuation in TDMA (Time Division Multiple Access) technique, a method for reducing data transmission rate in case of excessive attenuation, or a method for enhancing error correction capability by providing spare redundancies in a coding method. These methods mainly use a very basic and simple method for compensating rain
5 attenuation, so that the compensation range is limited and efficiency of rain attenuation compensation is also limited. In addition, these methods do not provide a detailed method for allocating a proper transmission method by estimating rain attenuation and then predicting attenuation at the next sampling time.

SUMMARY OF THE INVENTION

10 Accordingly, the present invention is directed to a rain attenuation compensation method using an adaptive transmission technique and a system using the same that substantially obviate one or more of the problems due to limitations and disadvantages of the related art.

It is an object of the present invention to provide a rain attenuation
15 compensation method and an apparatus for the same, which uses both an adaptive coding/decoding method using a block turbo code and an adaptive modulating/demodulating method using M-ary PSK (Phase-Shift Keying) modulation method as an adaptive transmission method, estimate a signal-to-noise (S/N) ratio from a PSK-modulated received signal at a receiving end, predict S/N ratio at the next time point
20 by using the estimated S/N ratio, allocate the most appropriate transmission method, and thus obtain an economical and maximal transmission efficiency.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, a rain attenuation compensation method in a satellite communication system including a transmission end
25 having a plurality of transmission methods comprised of a combination of an adaptive coding method and an adaptive modulation method, a receiving end having a plurality of receiving methods comprised of a combination of an adaptive decoding method and an adaptive demodulation method, and a controller for estimating/predicting a signal-to-

noise(S/N) ratio and controlling both a transmission method and a transmission power of the transmission end and a receiving method of the receiving end, the rain attenuation compensation method for the controller includes the steps of:

- estimating a signal-to-noise(S/N) ratio of present time point, and predicting
- 5 a signal-to-noise(S/N) ratio of the next time point;
- determining a transmission method which is adequate to the predicted signal-to-noise (S/N) ratio of the next time point; and
- generating a control signal for requesting the change of the transmission method and transmission power of the transmission end and the receiving method of the
- 10 receiving end according to the determined transmission method, and transmitting/receiving a data through the changed transmission method.

According to the present invention, a recording media is provided, which is readable by a computer recording a program for executing a rain attenuation compensation method using the aforementioned adaptive transmission method.

- 15 In another aspect, a satellite communication system includes:
 - a transmission end comprising a plurality of transmission methods composed of the combination of an adaptive coding and an adaptive modulation;
 - a receiving end comprising a plurality of receiving methods composed of a combination of an adaptive decoding and an adaptive demodulation; and
 - 20 a controller which estimates a signal-to-noise (S/N) ratio of the signal received at the receiving end, predicts a signal-to-noise (S/N) ratio at the next time point, determines which of transmission methods is adequate to the predicted signal-to-noise (S/N) ratio of the next time point, controls both the transmission method and transmission power of the transmission end and the receiving method of the receiving end so as to allow
 - 25 the transmission end and the receiving end to transmit/receive the data through the determined transmission method, and adaptively controls the transmission method according to the signal-to-noise (S/N) ratio.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be

learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the scheme particularly pointed out in the written description and claims hereof as well as the appended drawings.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the present invention will be explained with reference to the accompanying drawings, in which:

Figure 1 shows a method for an adaptive coding/decoding using a block turbo code;

Figure 2 shows bit error rate performance of M-ary PSK modulation method;

Figure 3 is a block diagram of a satellite communication system using a rain attenuation compensation method using the adaptive transmission technique according to a preferred embodiment of the present invention;

Figure 4 is a flowchart illustrating a rain attenuation compensation method using the adaptive transmission technique according to a preferred embodiment of the present invention;

Figure 5 shows M-ary PSK signal constellation in a noise-free channel environment;

Figure 6 shows a method for estimating a received signal-to-noise (S/N) ratio shown in Figure 4;

Figure 7 shows a probability density function of M-ary PSK signal in a noisy channel environment;

Figure 8 shows a technique for estimating a signal-to-noise (S/N) ratio;

Figure 9 shows a characteristic of linear combination results according to the histogram of the signal-to-noise (S/N) ratio used for the signal-to-noise (S/N) ratio estimation technique;

Figure 10 shows the estimated results of the signal-to-noise (S/N) ratio;

5 Figure 11 is a flowchart illustrating a step for predicting a signal-to-noise ratio of the next time point shown in Figure 4; and

Figure 12 is a flowchart illustrating a step for determining a transmission method shown in Figure 4.

DETAILED DESCRIPTION OF THE INVENTION

10 Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

A rain attenuation compensation method using the adaptive transmission technique according to a preferred embodiment of the present invention will now be described in detail.

15 In case of compensating rain attenuation by using an adaptive transmission technique in a satellite communication system using a high frequency band over Ku-band, the rain attenuation compensation method according to the present invention uses an adaptive coding/decoding method using a block turbo code and M-ary PSK adaptive modulation/demodulation method as an adaptive transmission technique.

20 In the adaptive coding/decoding method using a block turbo code, two kinds of methods are employed to adjust the coding gain according to the quantity of attenuation. The related detailed description is disclosed in the article "Adaptive Coding/Decoding Method in Satellite Communication System using Block Turbo Code" published by Soo Young, KIM et al. in JCCI 2000, volume 1 at pp. 419-422.

25 Figure 1 shows a method for an adaptive coding/decoding using a block turbo code. Referring to Figure 1, in order to employ a linear block code where the length of information word is 'k' and the length of a code word is 'n', an information frame comprised of k^2 bits is constructed. In a normal case, as to the information frame having k^2

bits, a general block coding method for sequentially performing k-times block coding operations for k bits is employed to transmit a plurality of coding frames of nk. With respect to a plurality of received signal frames of nk, soft decision Viterbi decoding methods are sequentially performed for k-times as to the block code of n received signals at a time, thereby restoring a plurality of information bit frames of k^2 .

In addition, if it is determined that additional coding gain is needed because of an excessive attenuation, as to the information frame composed of k^2 bits, block coding operations of k-times for k bits are sequentially performed for each row, and block coding operations of k-times for k bits are sequentially performed for each column, therefore, bits of $(2nk-k^2)$ are transmitted. In case of decoding, an iterative decoding method using a soft decision output Viterbi algorithm is employed. In this case, there are several advantages that the same coding construction is used and only a little modification of the decoding method is needed to at the receiving end.

Adaptive transmission technique using M-ary PSK modulation method properly allocates 8-PSK, QPSK (Quadrature Phase Shift Keying), BPSK and a symbol repetition BPSK according to the quantity of attenuation. That is, in case of the lowest attenuation, 8-PSK modulation method having the lowest efficiency in a power gain aspect and a superior frequency efficiency is employed. As the attenuation gradually increases, other methods having higher power gain, such as QPSK or BPSK method, are selectively employed.

Figure 2 is a graphical representation of the bit error rate (BER) of M-ary PSK modulation method. For example, assuming that a bit error rate performance required to a system is 10^{-6} , if 8-PSK modulation method is switched to QPSK method, about 5dB power gain can be obtained. In other words, if the system employs 8-PSK method in a normal case and signal attenuation over 5dB occurs, the system will change the modulation method to QPSK. At this time, there is no damage in the total link performance. In this manner, if the signal attenuation gradually increases, the QPSK method is sequentially switched to BPSK, 2 SR (Symbol Repetition) BPSK, and 4 SR BPSK.

This concept is applied to an adaptive coding method in the same manner. That is, in a normal case, a method shown in Figure 1(a) is employed. If a signal attenuation gradually increases, other method as shown in Figure 1(b) requiring less power is employed in order to maintain the bit error rate (BER) performance instead of the method of Figure 1(a).

Figure 3 is a block diagram of a satellite communication system according to the present invention. Referring to Figure 3, the satellite communication system includes a transmission part 310 comprising N transmission methods composed of a combination of an adaptive coding method using a block turbo code and M-ary PSK modulation methods, a receiving part 320 comprising N receiving methods composed of a combination of an adaptive decoding method using a block turbo code and M-ary PSK demodulation methods, and a controller 330 for controlling the transmission method and transmission power of the transmission part 310 and the receiving method of the receiving part 320 by estimating/predicting a receiving signal-to-noise (S/N) ratio and determining an adequate transmission/reception method. The rain attenuation compensation method using an adaptive transmission technique according to the present invention is made in the controller 330.

Figure 4 is a flowchart illustrating a rain attenuation compensation method using an adaptive transmission technique according to a preferred embodiment of the present invention. Referring to Figure 4, a controller 310 estimates (S401) the signal-to-noise (S/N) ratio of the present time point on the basis of received M-ary PSK modulation signal, predicts (S402) the signal-to-noise (S/N) ratio of the next time point on the basis of the estimated received signal-to-noise value at the past and present time points. The controller 310 determines (S403) a transmission method proper to the next time point on the basis of the predicted signal-to-noise (S/N) ratio, compares the determined transmission method with a transmission method of the present time point, determines (S404) whether a transmission method should be changed or not, and thus generates (S405) a transmission method switching command. According to the transmission method switching command,

the transmission part 310 and the receiving part 320 change the transmission method and the receiving method, and then transmit a data in the step S406.

Figure 5 shows a method for estimating the signal-to-noise (S/N) ratio of the present time point according to a preferred embodiment of the present invention. Figure 6 shows M-ary PSK signal constellation in a noise-free channel environment.

Referring to Figure 5 and 6, the level of the received signal modulated by M-ary PSK method is normalized (S501). In case of a noise-free channel, M-ary PSK modulated symbol signal having a symbol energy of 1 is shown in Figure 6.

Figure 7 shows probability density functions of M-ary PSK signal in a noisy environment. If channel noise is added to the M-ary PSK modulated symbol signal, the probability density function of either a real part or an imaginary part of a received M-ary PSK symbol is graphically represented in Figure 7. In case of the modulation method with higher order over QPSK, the real part and the imaginary part have the same statistical characteristic, so that the real part and the imaginary part are used all to estimate the value of signal-to-noise (S/N) ratio. Then, a quantization is performed (S502) on the normalized signal of the step S501, and a histogram of the quantized values is obtained (S503). Weighting values are given to the quantized signal values of the step S502 and the weighted signal values are linearly combined (S504).

The normalization step S501 determines a normalization reference level according to a control signal indicating the modulation method of the received signal, multiplies an inverse number of the determined normalization reference level by the received signal, and thus performs a normalization. The quantization step S502 and the histogram calculation step S503 obtain the absolute values of either real part or imaginary part of the received symbols, quantize the absolute values in predefined levels, observe the number of symbols included in each quantization level, and thus obtain a histogram.

Figure 8 shows an example of obtaining a histogram by using 16-level quantization on either real part or imaginary part of received M-ary PSK symbols, applying a square-type weight to this result, then combining the results linearly, and finally estimating the signal-to-noise (S/N) ratio. The weights are defined as the squared integer

values in consideration of the complexity when it is implemented in hardware. A plurality of weighted values such as 0, 1, 4, and 9 et al. are symmetrically applied from the central point of quantized signal level '1'.

Figure 9 shows a characteristic of a linear combination value wherein the square-type weight in the 16-level quantization is applied. In Figure 9, a curve depicts characteristic of average value of the linear combination result, a bar graph in a vertical direction indicates a standard deviation from an average value. Figure 9 indicates monotonically decreasing characteristics according to a received signal-to-noise (S/N) ratio. A relation between the received signal-to-noise (S/N) ratio and the linear combination result of Figure 9 is employed to estimate a received signal-to-noise (S/N) ratio on the basis of a linear combination result obtained under a certain channel.

Then, a step for converting the obtained combination result to signal-to-noise (S/N) ratio is performed (S505). At this time, a relation between a linear combination result value shown in Figure 9 and a received signal-to-noise (S/N) ratio obtained by a simulation is made as a relation table, and a signal-to-noise (S/N) ratio result corresponding to a linear combination result value previously estimated in a channel is outputted (S506) by using the relation table. After that, the obtained signal-to-noise (S/N) ratio estimation result is outputted (S507).

Figure 10 is a graphical representation illustrating a performance of an estimation result of the received signal-to-noise (S/N) ratio by using the relation between the signal-to-noise (S/N) ratio and the linear combination result in Figure 9. In Figure 10, the curve indicates averaged values of a signal-to-noise (S/N) ratio estimation result, and the vertical bar on the curve indicates a standard deviation from the average value. From this result, the estimation of the received signal-to-noise (S/N) ratio using 16 quantization levels has an average characteristic near to a linear shape, up to about 20 dB as a maximum value. And, the standard deviation is not large.

In the meantime, a method for predicting a signal-to-noise (S/N) ratio of the next time point on the basis of signal-to-noise (S/N) ratio values previously estimated at the present and past time points is disclosed in Korean Patent Application No. 2000-4111.

Figure 11 is a flowchart illustrating a step for predicting a received signal-to-noise ratio according to a preferred embodiment of the present invention.

Referring to Figure 11, a time t is initialized (S1101). A low pass filtering action is performed (S1103) for the estimated signal-to-noise (S/N) ratio values. On the basis of the variation of the filtered signal-to-noise (S/N) ratio values, a signal-to-noise (S/N) ratio at the next time point is predicted (S1104). The low pass filtering (LPF) action is employed to eliminate a fast variation in the estimated signal-to-noise (S/N) ratio values, wherein the magnitude is changed at an interval shorter than a response delay time of a system. Such a LPF action is used to eliminate a high-speed variation in signal-to-noise (S/N) ratio values, but causes a delayed variation of the estimated values. Accordingly, in order to reduce a delay error caused by the low pass filter (LPF), an prediction error correction step (S1105) is performed, wherein a correction value is proportional to the average prediction error.

Since the variation of signal-to-noise (S/N) ratio faster than a system response time within a smaller width is not considered in the prediction step, real signal-to-noise (S/N) ratio is deviated from the predicted value within a small range due to scintillation. At this time, if the real signal-to-noise (S/N) ratio value is higher than the predicted value, a deterioration of service quality does not occur. However, in the opposite case that the real signal-to-noise (S/N) ratio is lower than the predicted value, a transmission method conversion proper to the real value may not made or a transmission power may be adjusted with a magnitude smaller than a required magnitude, thereby a deterioration of service quality can occur. In order to prevent this case, a method making the predicted value lower than the real value is also needed. The present invention employs a method for adding a margin to the predicted value, wherein a fixed margin having a predetermined negative (-) magnitude is added to the predicted value and a variable margin estimated in proportion to a standard deviation of the prediction error in step S1106 is also added in step S1107.

More specifically, the step S1104 for prediction a signal-to-noise (S/N) ratio of the next time point on the basis of a variation of the Low-Pass-Filtered signal-to-noise

(S/N) ratio is employed to predict a magnitude of the signal-to-noise (S/N) ratio after a predetermined time, on the basis of a variation of a predetermined degree for a difference between a received signal-to-noise (S/N) ratio at the past time point and a received signal-to-noise (S/N) ratio at the present time point.

5 The prediction error correction step S1105 delays the predicted signal-to-noise (S/N) ratio by an prediction time, obtains an prediction error by calculating a difference between a real received signal-to-noise (S/N) ratio before the low pass filtering and the delayed signal-to-noise (S/N) ratio, estimates an average value of the prediction errors, and finally corrects the predicted signal-to-noise (S/N) ratio to be proportional to the
10 average prediction error. Herein, the average value of the prediction errors is obtained by a low pass filtering, such as a discrete-time feedback filtering, on the prediction error.

 A step S1107 for allocating a prediction margin estimates a standard deviation of the prediction error, calculates a variable prediction margin proportional to the standard deviation, and adds the variable prediction margin and a fixed prediction margin
15 of a predetermined size to a prediction value. Here, the dispersion of the prediction error is obtained by a low pass filtering, such as a discrete-time feedback filtering, on the prediction error and the average prediction error. In addition, the variable prediction margin is estimated by using a constant proportional to a difference between a time rate and a required probability, the time rate causing a negative (-) prediction error until the
20 present time point.

 In the meantime, a method for determining a transmission method in a rain attenuation compensation method using the adaptive transmission techniques is disclosed in Korean Patent Application No. 1999-61842. Figure 12 is a flowchart illustrating a method for determining a transmission method according to a preferred embodiment of the
25 present invention.

 Referring to Figure 12, steps S1201 and S1202 are provided to calculate a cumulative value of transmission efficiencies estimated by the past signal-to-noise (S/N) ratio. If a variation of a received signal is at a high value, an accumulation parameter is reduced to give more importance on the present transmission efficiency rather than the past

transmission efficiency. On the contrary, if a variation of a received signal is at a low value, the accumulation parameter is increased to reflect the past transmission efficiency.

For this purpose, a slope $\Delta R(t)$ on the past and present received signal-to-noise(S/N) ratio values is obtained by using a mathematical equation 1.

$$\Delta R(t) = \frac{R(t) - R(t-1)}{t - (t-1)} = R(t) - R(t-1) \quad [\text{Equation 1}]$$

In the Equation 1, $R(t)$ is a received signal-to-noise (S/N) ratio measured at the present time point, $R(t-1)$ is the past signal-to-noise(S/N) ratio prior to $R(t)$, and t is a sampling time and an integer indicated as either '0' or positive integer. By using the aforementioned instantaneous slope $\Delta R(t)$, a accumulation parameter λ of the present time point is obtained by a mathematical equation 2.

$$\lambda = \frac{1}{x|\Delta R(t)| + 1} \quad [\text{Equation 2}]$$

In the Equation 2, x is a constant being a positive(+) real number, and is employed to adjust the accumulation parameter value according to the slope. If a small number below 0.5 is selected as a value of x , the accumulation parameter λ is less sensitive to a variation of a slope magnitude. If a number near to 1 is selected as a value of x , the past transmission efficiency has more importance. If the value of x increases, the accumulation parameter λ becomes more sensitive to a slope. If a number near to 1 is selected as a value of x , the accumulation parameter λ becomes very sensitive to a value in the vicinity of a slope 1. In addition, if the value of x is over 1, the accumulation parameter λ is less sensitive to a slope variation, but an importance about the past transmission efficiency is reduced in contrary to the above case that a small number below 1 is selected as a value of x .

A step S1203 is provided to estimate the transmission efficiency about each of N transmission methods according to signal-to-noise (S/N) ratio values. Here, the

transmission efficiency $S(t)$ is defined as a bit rate that is successfully received without an error as shown in a mathematical equation 3.

$$S(t) = (1 - P_b(R, D))R_b(D) \quad [\text{Equation 3}]$$

In the Equation 3, $P_b(R, D)$ indicates a bit error rate (BER) of a transmission method D, has a different value according to the signal-to-noise (S/N) ratio R and a transmission method D, and $R_b(D)$ indicates a transmission bit rate when a communication service is made with the transmission method D.

For a relative comparison of each transmission method, the present invention uses a transmission efficiency normalized by the transmission bit rate $R_b(D)$ of each transmission method.

Further, a bit error rate (BER) of a transmission method having a higher BER as compared with a specific bit error rate (BER) P_b^* required by a communication service is determined as a constant P (for example, a number 1) near to the number '1', so that the transmission efficiency not satisfying a service quality becomes reduced to a very small number. Transmission efficiency of each transmission method is obtained by a mathematical equation 4.

$$S(t) = \begin{cases} 1 - P_b(R, D), & \text{if } P_b(R, D) \leq P_b^* \\ 1 - P, & \text{if } P_b(R, D) > P_b^* \end{cases} \quad [\text{Equation 4}]$$

Then, a step S1204 is provided to calculate a cumulative transmission efficiency of each transmission method by using the accumulation parameter λ calculated by the Equation 2.

The cumulative transmission efficiency $\bar{S}(t)$ is obtained by a mathematical equation 5

$$\bar{S}(t) = \sum_{l=0}^{L-1} \lambda^l S(t-l) \quad [\text{Equation 5}]$$

In the Equation 5, the cumulative transmission efficiency $\bar{S}(t)$ is the sum of transmission efficiencies exponentially weighted by the accumulation parameter λ during the predetermined period L.

5 A step S1205 is provided to select a transmission method of which the cumulative transmission efficiency has a maximum value.

Then, a step S1206 is employed to determine whether the selected transmission method is a higher-priority method or a lower-priority method as compared to the past transmission method. In case of the lower-priority method, a step S1209 for
10 transmitting a command to both a transmission part and a receiving part is performed so that a switching toward the selected transmission method occurs.

On the contrary, if the selected transmission method is a higher-priority method as compared to the past transmission method, in order to determine whether the present selection is a stable or not, a step S1207 is employed to check whether the same
15 transmission method is selected during a specific time period. In case that the same selection is successively made during the specific time, a switching toward the present selected transmission method is commanded by a step S1209. If not, the past transmission method is maintained without a switching command and an unnecessary switching is avoided in a step S1208.

20 As described above, according to the present invention, a rain attenuation compensation method and an apparatus using the same are provided to effectively compensate a signal attenuation caused by a rain in a satellite communication system using a high frequency band over Ku-band. The inventive method and apparatus have a real-time adaptability, directly estimate a signal-to-noise (S/N) ratio not a receiving signal level, and
25 thus effectively allocate more accurate adaptive transmission method. In the light of a prediction technique, the present invention can be simply embodied by a simple process on the basis of the variation of the filtered signal-to-noise (S/N) ratio values. Besides, in case

of selecting a transmission method, the present invention can avoid frequently switching the transmission method.

In particular, in case that a switching from a low-priority transmission method to a high-priority transmission method is requested, the present invention delays the switching until the request is sustained, thereby preventing the deterioration of transmission efficiency and service quality deterioration. In addition, the present invention achieves a self-efficiency of a transmission method such as an adaptive coding method using a block turbo code, thereby making more economical service.

Although representative embodiments of the present invention have been disclosed for illustrative purposes, those who are skilled in the art will appreciate that various modifications, additions and substitutions are possible without departing from the scope and spirit of the present invention as defined in the accompanying claims and the equivalents thereof.